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Anthropometric Assessment for Ergonomic School Furniture Design to Prevent Student Discomfort and Musculoskeletal Disorders

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Abstract

Classroom furniture plays a critical role in shaping the comfort, posture, and academic performance of students. However, a widespread mismatch between school furniture dimensions and students' anthropometric characteristics often results in discomfort and musculoskeletal disorders (MSDs). This study aims to assess the anthropometric measurements of primary and secondary school students in Osun State, Nigeria, to recommend ergonomically appropriate classroom furniture dimensions. Anthropometric data were collected from 900 students (124 in primary and 776 in secondary schools), equally divided by gender and ranging in age from 6 to 20 years. Measurements included sitting height, elbow height, shoulder height, popliteal height, buttock-popliteal length, and other key dimensions, using a standard anthropometer. Existing classroom furniture dimensions were also recorded. Using Microsoft Excel 365, percentiles (5th, 50th, and 95th) were computed to determine appropriate design values. The analysis revealed significant mismatches between current furniture and students' body dimensions, contributing to poor posture and discomfort. Design recommendations were developed for seat and desk dimensions tailored to both primary and secondary students. For instance, the ideal seat height is 28.35 cm for primary and 37.55 cm for secondary students, while desk surface heights range from 42.80–45.61 cm and 50.73–54.87 cm, respectively. The study concludes that incorporating anthropometric data into classroom furniture design can significantly reduce student discomfort and prevent long-term musculoskeletal issues. It emphasizes the urgent need for region-specific ergonomic standards to ensure student well-being and enhance academic productivity.

1. Introduction

Classroom furniture, particularly chairs and desks, forms the foundation of a functional learning environment and is essential for every school setting [1]. These pieces of furniture significantly influence the daily experiences of students, affecting their comfort, posture, and ability to focus [2]. When well-designed, they support healthy physical development and enhance learning efficiency. Conversely, Furniture that is poorly designed or not suited to the user may result in discomfort and chronic health complications, such as musculoskeletal disorders [3].

The anthropometric measures of the intended users are supposed to be used to define the dimensions of school furniture, among other things. To guarantee that students keep the proper sitting position, anthropometric measurements such as popliteal height, knee height, buttock to popliteal length, and elbow height have to be used in furniture design [4]-[5]. An increasing amount of data indicates that students experience high levels of neck and back pain [6]-[9]. These types of musculoskeletal issues cause discomfort in kids and have a long-term detrimental impact on their health [10]-[11]. Nonetheless, studies have indicated that poorly made classroom furniture and awkward sitting positions are frequently the source of children's musculoskeletal aches [12]-[13]. Furthermore, Oke et al. [14] established that when school furniture dimensions do not match the anthropometric measurements of the kids, it will cause musculoskeletal pain in various body regions when the kids utilize it for learning.

Students face severe issues as a result of the mismatch between their anthropometric measurements and the furniture in their school. Researchers have shown that school furniture can significantly affect students' mental and physical health, influence their social behavior, and, in some cases, cause a dislike for learning and a reluctance to attend classes [1]-[2], [15]. Valikhani et al. [1] found that children demonstrated a modest but meaningful improvement in on-task behavior and adopted more attentive, orderly sitting postures when using ergonomically designed chairs. Similarly, Altaboli et al. [15] reported that the rate of mismatch between student body dimensions and classroom furniture increases with age and body size, rising from approximately 72% in fourth grade to 82% in fifth grade. This suggests that as students grow, the available space per child becomes increasingly inadequate. Their study also emphasized that such mismatches can force students into awkward and constrained postures, potentially leading to musculoskeletal discomfort that may persist into adulthood.

It is now challenging to get kids to sit up straight (the "right angle") in the classroom due to uncomfortable chairs, which leads to restlessness, fidgeting, and movement of school chairs all the time. Inadequate furniture is linked to pain in various body parts such as the neck, back, and waist in British schools [9],[16](. General discomfort during sitting is strongly correlated with thigh length and seat depth mismatches [17]-[19]. Additionally, there is a strong correlation between reported neck and shoulder pain and the mismatch between the height of the desk and the elbows when seated. In the meantime, it has been demonstrated that anthropometric data may be used to effectively design classroom furniture [20].

There are a few anthropometric statistics available in Nigeria that offer basic descriptive measurements such as body measurements, composition, and nutritional status [21]-[23]. Given that school-age children are susceptible to health and safety hazards arising from the physical state of classrooms and the mismatch between the size of the student body and the furniture in the classroom [14],[24]. The study aims to collect anthropometric data of primary and secondary school students in Osun State, Nigeria, and establish standard selection criteria and dimensions that are necessary for designing classroom furniture for students. This is with a view to design an anthropometrically appropriate school furniture and improve student’s physical health and correctly influence sitting posture, which may affect their adulthood sitting habits.

2. Method

A comprehensive methodology that included study sample, data collection, furniture dimension, and statistical analysis and design was carried out to assess the level of mismatch between the student’s body size and furniture dimension, and recommend appropriate classroom furniture dimension for the students.

2.1 Study Sample

The research was conducted across twelve primary and secondary schools located across Ife Central, Ife East, Ede South, Ede North and Ayedaade Local Government Area all in Osun State with the consent and approval of the schools’ principals. In this study, equal number of male and female students were randomly selected from each school. A total of 124 primary school students and 776 secondary school students gave information consent. Students in primary school ranged from age five (5) to twelve (12) years old, while those in secondary school were eleven (11) to twenty (20) years. Student’s body sizes were measured using standard anthropometric techniques [14]. In all anthropometric measurements, the subject sat comfortably upright without wearing shoes.

The measurements were conducted in the different classrooms of each of the chosen schools in Osun State on a level floor. The study sample also played an important role in obtaining a representative sample of school students. A few characteristics were taken into consideration, such as age, gender, and socioeconomic level.

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2.2 Data Collection

Students grow differently with age [25]-[26]. A good example is before puberty, legs grow faster than trunks, but during adolescents' growth spurts, trunks grow more rapidly than legs [27]-[28]. So, considering the age of the subjects; weight and body sizes of the subjects (Fig. 1) were measured. All dimensions were taken as described by Oke et al., [14].

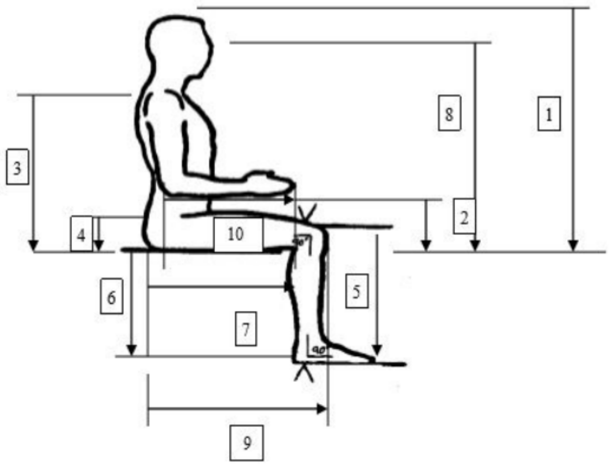

Fig. 1 *Anthropometric data collected [3]*

1. Sitting height: The student sits upright, hands resting on thighs, arms dangling at sides, and head in the Frank Fort plane. A meter tape was used to determine the distance between the head's vertex when the hair was pressed down and the surface of the seat as shown in Fig. 1.
2. Sitting Elbow height: Measured vertically from the underside of the elbow known as the olecranon to the surface of the seat, when the elbow flexed at 90°. During the measurement, the student sits upright with thighs supported and legs hanging without obstruction. Arms hang down from the shoulders, and the forearms are kept level. This dimension, helps in setting the armrest height.
3. Sitting Shoulder height: While seated in an erect posture, the student keeps their upper arms besides them with hands resting on their thighs. The displacement between the acromion to the surface of the seat is determined using a tape measure. This is important for establishing the appropriate upper backrest height.
4. Thigh Clearance: Seated upright with relaxed, extended legs, the vertical displacement from the top of the student's thigh at its junction with the abdomen to the surface of the seat is measured and recorded. Thigh clearance, along with popliteal and shoe clearances, are important reference points in defining table height.
5. Sitting Knee Height: The vertical span between the surface of the floor and the top of the knee is determined while the student is allowed to upright on the chair, maintaining a right-angle bend at the knees. The measurement is taken using a meter tape.
6. Popliteal height: The height from beneath the thigh, just behind the knee, is measured in this procedure. The student sits fully upright, thighs supported, and the seat surface extending into the knee hollow, with lower legs dangling without restriction. This is essential in defining the correct seat height.
7. Buttock-Popliteal length: The buttock-popliteal length is the horizontal distance from the rearmost point of the uncompressed buttocks to the backside of the lower leg at the knee. While the subject sits erect, thighs supported, and seat extending towards the knee hollow, with lower legs hanging, this measurement is taken with the knees at a 90° angle. The distance from the posterior surface of the buttocks to the popliteal area is recorded using a measuring block positioned at the front edge of the seat. This dimension is necessary for setting seat depth.
8. Face height: This refers to the vertical distance between the eyes or face and the sitting surface, recorded with the help of a meter tape.
9. Buttock-knee length: Seated erect with feet flat and knees at a right angle, the subject keeps arms at the sides and hands resting on the thighs. The horizontal distance from the rear edge of the buttocks to the front edge of the knee is measured with a tape held parallel to the length of the thigh.

10. Forearm-Hand length: Seated erect, the student maintains a 90° angle between the upper and lower arms, with the hand fully extended. The distance from the rear end of the elbow to the tip of the longest finger is recorded using a measuring tape. This forearm-hand dimension is required to establish the correct depth of the table.
11. Body mass: A calibrated weighing scale was used to record the student's weight as they stood on the device.

2.3 Furniture Dimension

All dimensions were taken as described by Altaboli et al. [15]

1. Seat depth: The seat depth of the chair is the horizontal distance from the back of the seat to the point where the buttocks are presumed to begin, towards the front edge. This depth must be adequate to avoid contact between the front of the seat and the area behind the knees (popliteal area).
2. Seat slope: It describes both the angle and direction of the seat's downward or upward pitch.
3. Table height: It is the distance measured vertically from the floor to the upper edge of the table's front surface.
4. Table clearance: It is the vertical distance from the floor up to the bottom surface of the desk or table's front edge.
5. Table slope: It is defined by the tilt angle of its top surface.

2.4 Statistical Analysis and Design

In this study, Microsoft Excel 365 programs were used to analyze the data. The analysis was done by finding the mean, standard deviation (SD), 5th percentile, 50th percentile, and 95th percentile of the anthropometric data. In addition, the minimum and maximum dimensions, as well as body mass, were included.

3. Results and Discussion

3.1 Anthropometric Study

A total of 11 anthropometric characteristics of primary and secondary school students measured on population of 124 primary school students and 776 secondary school students are as shown in Table 1 and 2 respectively. These tables help identify key body measurements that help to ensure chairs and desks are tailored to students' physical needs. By including statistical parameters like mean, standard deviation, and percentiles (5th, 50th, and 95th), designers can accommodate a wide range of student sizes, from the smallest to the largest, minimizing discomfort and health risks.

This data-driven approach ensures that school furniture supports proper posture, reduces musculoskeletal stress, and enhances students' focus and classroom performance. For example, using the 5th percentile for seat height avoids cutting off circulation in shorter students, while the 95th percentile for seat width prevents crowding for broader students.

Table 1 *Anthropometric data summary for students in selected primary schools across Osun State*

	Population	Mean	Standard Deviation	Minimum	Maximum	5th Percentiles	50th Percentiles	95th Percentiles
Age (Yrs.)	124	8.79	1.9	5	12	5	9	12
Sitting Height [SH] (cm)	124	63.2	5.2	48.3	83.2	56.0	62.2	71.1
Sitting Elbow Height [SEH] (cm)	124	16.5	2.1	10.2	21.4	14.0	16.3	20.3
Sitting Shoulder Height [SSH] (cm)	124	39.1	4.0	26.7	50.2	33.0	38.9	45.3

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	Population	Mean	Standard Deviation	Minimum	Maximum	5th Percentiles	50th Percentiles	95th Percentiles
Thigh Clearance [TC] (cm)	124	15.1	2.8	8.9	23.5	11.4	15.2	20.2
Sitting Knee Height [SKH] (cm)	124	41.0	4.7	29.2	54.6	33.9	40.6	47.9
Popliteal Height [PH] (cm)	124	33.6	4.5	20.3	50.6	27.9	33.7	40.5
Buttock Popliteal Length [BPL] (cm)	124	39.7	3.5	30.5	47.0	33.2	40.2	45.7
Buttock Knee Length [BKL] (cm)	124	48.1	4.3	36.8	60.7	41.9	48.3	55.6
Forearm Hand Length [FHL] (cm)	124	34.9	4.7	25.4	49.3	27.9	34.3	43.0
Hip Breadth [HB] (cm)	124	21.1	2.5	16.4	27.6	17.9	20.5	25.8
Body Weight [BM] (Kg)	124	23.5	4.8	14.0	40.3	18.0	22.0	32.9

Table 2 *Anthropometric data summary for students in selected secondary schools across Osun State*

	Population	Mean	Standard Deviation	Minimum	Maximum	5th Percentile	50th Percentile	95th Percentile
Age (Yrs.)	776	15	1.97	10	20	12	15	18
Sitting Height [SH] (cm)	776	75.3	5.79	49.8	94	66.04	75.18	83.96
Sitting Elbow Height [SEH] (cm)	776	17.5	2.79	10.2	26.7	12.73	17.71	22.34
Sitting Shoulder Height [SSH] (cm)	776	47.9	4.06	33.0	57.3	40.64	48.26	54.39
Thigh Clearance [TC] (cm)	776	18.5	3.71	9.2	29.1	12.70	18.05	24.16

	Population	Mean	Standard Deviation	Minimum	Maximum	5th Percentile	50th Percentile	95th Percentile
Sitting Knee Height [SKH] (cm)	776	51.1	3.84	38.1	59.6	44.72	50.83	57.15
Popliteal Height [PH] (cm)	776	42.2	3.24	31.5	53.2	37.10	41.91	47.28
Buttock Popliteal Length [BPL] (cm)	776	46.2	6.07	33.3	62.3	38.10	45.24	58.35
Buttock Knee Length [BKL] (cm)	776	54.3	6.21	40.5	74.2	45.70	53.34	65.82
Forearm Hand Length [FHL] (cm)	776	44.4	3.94	28.9	54.5	38.10	44.45	50.81
Hip Breadth [HB] (cm)	776	29.1	4.1	18.8	45.1	22.26	28.96	34.97
Body mass [BM] (kg)	776	40.7	7.21	19.0	59.3	28.75	40.65	53.00

3.2 Design of School Furniture

The design of school furniture may be influenced by a variety of factors, including education, economics, culture, and ergonomics. This study takes ergonomic factors into account. The relevance of the study results cannot be guaranteed, depending on how they are presented. For designers' convenience, the results of this study are presented in percentiles. For school furniture design (mainly chairs, and tables), designs shown in Table 3 and 4, Figure 2 and 3 respectively are provided with body measurements relevant to their design, as recommended by Ismaila et al. [3].

Table 3 *Dimensions recommended for chairs and tables for primary schools in Osun State*

Features	Anthropometric Measure	Design Recommended Dimension	Design criteria
Seat surface height	Popliteal Height	28.35 cm	5th percentile of popliteal height + 0.45 cm shoe allowance
Seat surface depth	Buttock Popliteal Length	33.2 cm	5th percentile of buttock popliteal length
Seat surface width	Hip Breadth	29.67 cm	95th percentile of hip breadth + 15% clothing allowance
Seat angle to horizontal		0 degree	

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Features	Anthropometric Measure	Design Recommended Dimension	Design criteria
Upper seat backrest height	Sitting Shoulder Height	33.0 cm	5th percentile of sitting shoulder height
Lower seat backrest height	Armrest height	14.00 cm	5th percentile of sitting elbow height
Arm rest height	Sitting Elbow Height	14.00 cm	5th percentile of sitting elbow height
Backrest angle to horizontal		110^0	
Desk surface height	Sitting Elbow Height, Sitting Shoulder Height	Min = 42.80 cm Max = 45.61 cm	Max acceptable height = seat height + functional elbow height + shoe heel allowance
Desk surface width	Hip Breadth	33.54 cm	95th percentile of hip breadth + 15% clothing allowance + 15% clearance allowance
Desk surface depth	Forearm hand length	34.30 cm	50th percentile of forearm hand length
Desk angle to horizontal		15^0	

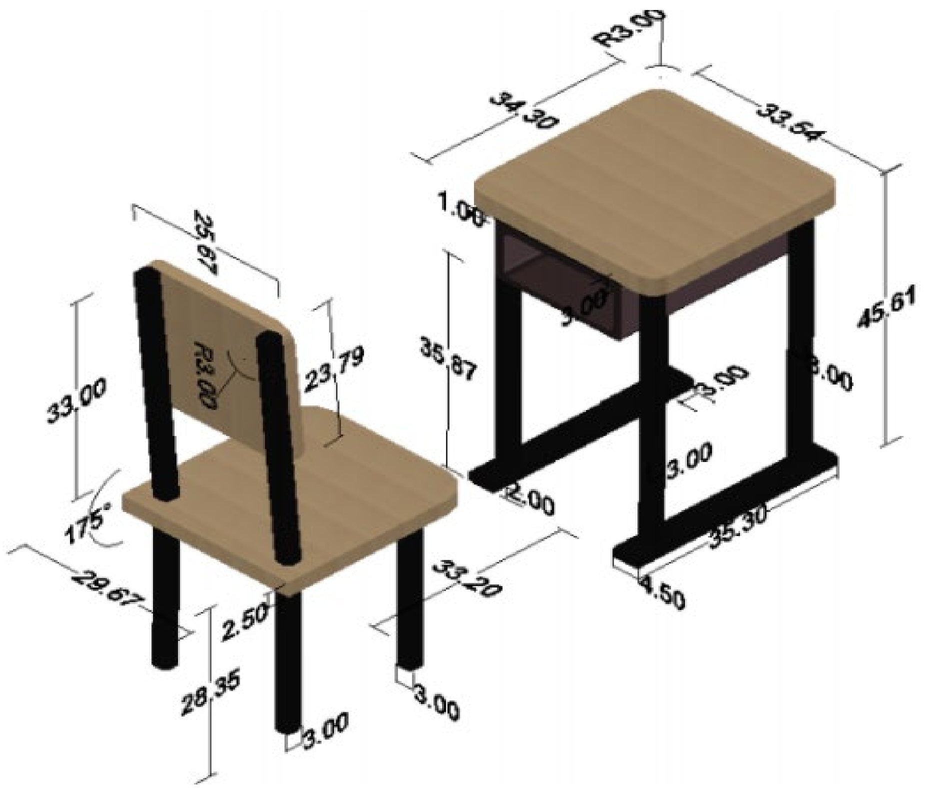

Fig. 2 *Design of table and chair using the recommended dimension for primary schools in Osun State*

Table 4 *Dimensions recommended for chairs and tables for secondary schools in Osun*

Features	Anthropometric Measure	Design Recommended Dimension	Design criteria
Seat surface height	Popliteal Height	37.55 cm	5th percentile of popliteal height + 0.45 cm shoe allowance
Seat surface depth	Buttock Popliteal Length	38.10 cm	5th percentile of buttock popliteal length
Seat surface width	Hip Breadth	40.22 cm	95th percentile of hip breadth + 15% clothing allowance
Seat angle to horizontal		0 degree	
Upper seat backrest height	Sitting Shoulder Height	40.64 cm	5th percentile of sitting shoulder height
Lower seat backrest height	Armrest height	12.73 cm	5th percentile of sitting elbow height
Arm rest height	Sitting Elbow Height	12.73 cm	5th percentile value of sitting elbow height
Backrest angle to horizontal		110^0	
Desk surface height	Sitting Elbow Height, Sitting Shoulder Height	Min = 50.73 cm Max = 54.87 cm	Max acceptable height = seat height + functional elbow height + shoe heel allowance
Desk surface width	Hip Breadth	45.46 cm	95th percentile of hip breadth + 15% clothing allowance + 15% clearance allowance
Desk surface depth	Forearm hand length	41.45 cm	50th percentile value of forearm hand length
Desk angle to horizontal		15^0	

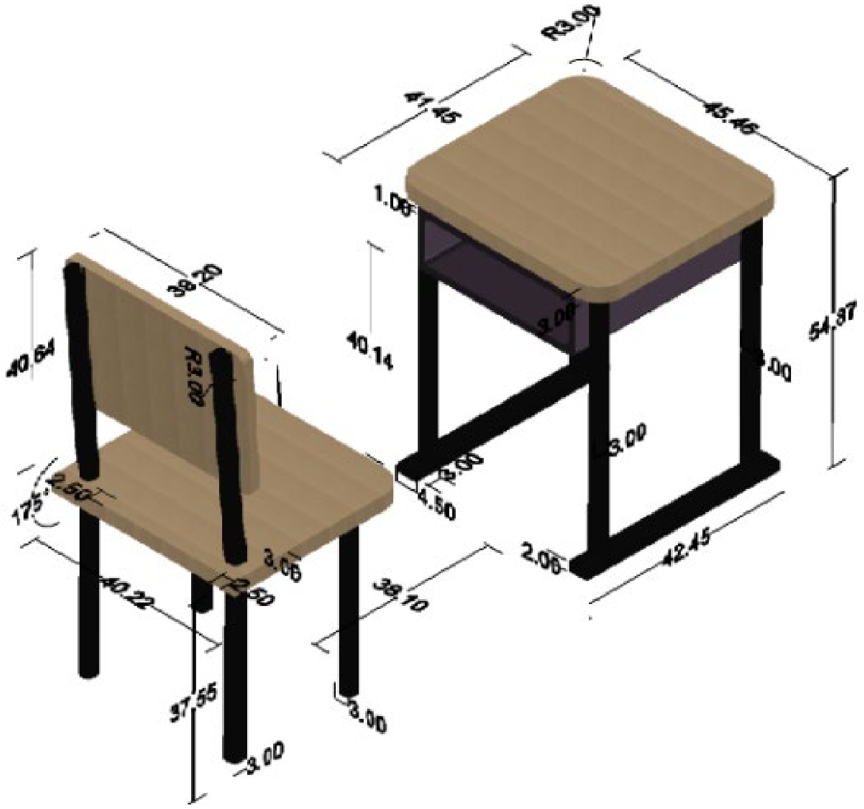

Fig. 3 *Design of table and chair using the recommended dimension for secondary schools in Osun State*

As shown in Tables 3 and 4, the dimensions of chairs and tables in primary and secondary schools are recommended in Osun State. The results show that primary and secondary schools should have seats that are 28.35 cm and 37.55 cm high, respectively. An extremely high seat surface compresses the underside of the thigh, resulting in discomfort and restricted blood flow [29]. Zacharkow [30] states that a sitting individual compensates for this by moving forward on the seat, resulting in the body losing its stability.

The results explain that the seat depth should be 33.2 cm and 38.10 cm for primary and secondary school respectively. The seat depth should not exceed these, as a larger depth prevents correct use of back support, causing kyphosis and uncomfortably curved spine. In the case of excessively shallow seats, the user may feel as if they are falling off and may not receive sufficient support for their lower thighs [31]-[32].

The study revealed that primary and secondary schools in Osun State should have seats width measuring 29.67 cm and 40.22 cm, respectively. To meet ergonomic standards, this research suggests upper backrest heights of 33.0 cm and 40.64 cm, and lower backrest heights of 14.00 cm and 12.73 cm for primary and secondary schools respectively. It is essential that a backrest be used in order to maintain a straight back while sitting, which reduces associated back pain [33]-[35]. Also included in the chair design are armrests measuring 12.73 cm and 14.00 cm in height. The inclusion of an armrest is essential as it lessens the load on the seat surface and alleviates stress on the spine and related areas [36]-[37].

The minimum and maximum height for primary school table is set at 42.80 cm and 45.61 cm respectively while for secondary school, it is set for 50.73 cm and 54.87 cm respectively. Maintaining appropriate table height in relation to the user is essential for supporting the lower body, shoulders, and torso, based on posture and arm positioning [38]-[40]. If the tabletop sits above elbow level, it forces the arms outward, leading to greater stress on the shoulders, arms, and neck [41]-[43]. A table that is too high may cause the person to hunch forward or raise their shoulders, increasing back and shoulder muscle strain as they lose backrest contact [44]-[46].

4. Conclusion

This study has demonstrated a significant mismatch between existing classroom furniture and the anthropometric characteristics of primary and secondary school students in Osun State, Nigeria. The analysis revealed that the current furniture designs do not adequately accommodate the physical dimensions of students, leading to discomfort, poor posture, and increased risk of musculoskeletal disorders. By collecting and analyzing anthropometric data from a large and diverse student population, the study proposed specific furniture dimensions that are ergonomically appropriate and inclusive for 95% of the student population.

The results underscore the importance of integrating anthropometric principles into school furniture design to improve students' comfort, support proper posture, and enhance learning efficiency. Specifically, recommended dimensions for seat height, seat depth, desk height, and backrest height were established for both primary and secondary school students using relevant percentile data. These recommendations serve as a practical guide for school administrators, furniture designers, and policymakers to implement ergonomic improvements in the learning environment.

In conclusion, adopting anthropometrically informed furniture designs in Nigerian schools is not just a matter of comfort but a vital step toward promoting students' physical well-being and academic success. Future research is recommended to expand similar studies across other regions in Nigeria to develop a comprehensive national database for ergonomic school furniture design.

Acknowledgement

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Abiola O., Oke A.;* ***data collection:*** *Olasunkanmi-Ojo M., Yusuf L.;* ***analysis and interpretation of results:*** *Abiola O. A., Oke A., Oladejo K.;* ***draft manuscript preparation:*** *Abiola O. A. All authors reviewed the results and approved the final version of the manuscript.*

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Appendix A: Anthropometric Measurement of Primary School Students

Appendix B: Anthropometric Measurement of Secondary School Students

Appendix C: Sample Questionnaire Used for the Survey

Section A: Demographic Information

1. **Age:** _______ years
2. **Gender:** ☐ Male ☐ Female
3. **Class Level:** ________________
4. **School Type:** ☐ Primary ☐ Secondary
5. **Name of School:** _________________________________
6. **Local Government Area (LGA):**
   ☐ Ife Central ☐ Ife East ☐ Ede North ☐ Ede South ☐ Ayedaade
7. **Dominant Hand:** ☐ Right-handed ☐ Left-handed
8. **Do you have any physical disability or musculoskeletal condition?**
   ☐ Yes ☐ No
   If yes, please specify: ______________________

Section B: Anthropometric Assessment
(For researcher/enumerator to complete using standard equipment)

1. Sitting Height (cm): __________
2. Sitting Elbow Height (cm): __________
3. Sitting Shoulder Height (cm): __________
4. Thigh Clearance (cm): __________
5. Sitting Knee Height (cm): __________
6. Popliteal Height (cm): __________
7. Buttock-Popliteal Length (cm): __________
8. Buttock-Knee Length (cm): __________
9. Forearm-Hand Length (cm): __________
10. Hip Breadth (cm): __________
11. Body Mass (kg): __________

Section C: Classroom Furniture Use and Discomfort

1. **Do you feel comfortable using your classroom chair?**
   ☐ Yes ☐ No
2. **Do you feel comfortable using your classroom desk?**
   ☐ Yes ☐ No
3. **Have you experienced pain or discomfort after sitting for long periods in class?**
   ☐ Yes ☐ No
   If yes, where? (You may tick more than one)
   ☐ Neck ☐ Shoulders ☐ Lower Back ☐ Upper Back
   ☐ Elbows ☐ Thighs ☐ Knees ☐ Hips
4. **Does your chair allow you to rest your feet flat on the floor?**
   ☐ Always ☐ Sometimes ☐ Never
5. **Is the desk height appropriate for writing comfortably?**
   ☐ Yes ☐ No
6. **How many hours a day do you spend in school?**
   ☐ 1–2 hours ☐ 3–4 hours ☐ 5–6 hours ☐ More than 6
7. **How many hours a day do you typically sit during school hours?**
   ☐ 1–2 ☐ 3–4 ☐ 5–6 ☐ More than 6
8. **Do you share your desk or chair with another student?**
   ☐ Yes ☐ No
9. **Do you need to adjust or reposition your body frequently due to discomfort?**
   ☐ Yes ☐ No
10. **Rate the overall comfort of your classroom furniture (1 = Very uncomfortable, 5 = Very comfortable):**
    ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Section D: Suggestions (Optional)

1. **What changes would you like to see in your classroom furniture?**

____
____
____

Thank you.

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